Ecological Momentary Assessment (EMA) for Research on Physical Activity and Eating

Saul Shiffman, Ph.D.
University of Pittsburgh
invivodata, inc.

What is EMA?

- Repeated real-time assessment of subjects' immediate behaviors and experiences in natural, real-world settings
- Often, intensive assessment with many assessments per subject
- e.g., diaries, self-monitoring, experience sampling
- e.g., having people record episodes of eating or exercise, "beeping" people at random for mood ratings

Ecological Momentary Assessment (EMA)

- Ecological
  - Real-world environments & experience
  - Ecological validity
- Momentary
  - Real-time assessment & focus
  - Avoid recall
- Assessment
  - Self-report
  - Repeated, intensive, longitudinal

Stone & Shiffman, 1994

Why EMA / Diaries?

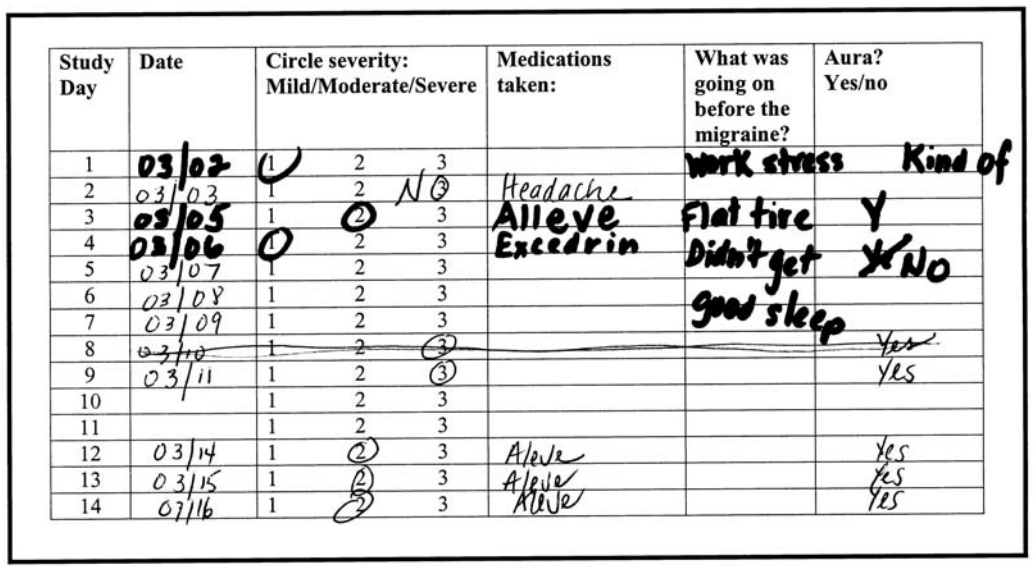
- Concern about recall bias
- Interest in real-world experience, ecological validity
- Interest in associations between environment, experiences, and outcome
- Interest in process over time

Problems with Retrospective Recall

- Recall is reconstruction
- Recall is often inaccurate
  - Especially for details, routine matters, and timing
- Recall is often biased
  - Heuristics used to reconstruct ‘memories’
  - Content influenced by extraneous factors, e.g., recall context, salience
- Summary processes may add bias
  - “How many?” “On average…” “How severe?”
  - Estimation, not enumeration

Real-Time Real-World Data

- Diary methods
- Compliance with timely entry continuing concern with written diaries
- (Data quality issues, too)



Study Day	Date	Circle severity: Mild/Moderate/Severe			Medications taken:	What was going on before the migraine?	Aura? Yes/no
1	03/02	(1)	2	3		work stress	Kind of
2	03/03	1	2	NO	Headache		
3	03/05	1	(2)	3	Aleve	Flat tire	Y
4	03/06	(1)	2	3	Excedrin	Didn't get good sleep	Y NO
5	03/07	1	2	3			
6	03/08	1	2	3			
7	03/09	1	2	3			
8	~~03/10~~	~~1~~	~~2~~	(3)			~~Yes~~
9	03/11	1	2	(3)			Yes
10		1	2	3			
11		1	2	3			
12	03/14	1	(2)	3	Aleve		Yes
13	03/15	1	(2)	3	Aleve		Yes
14	07/16	1	(2)	3	Aleve		Yes

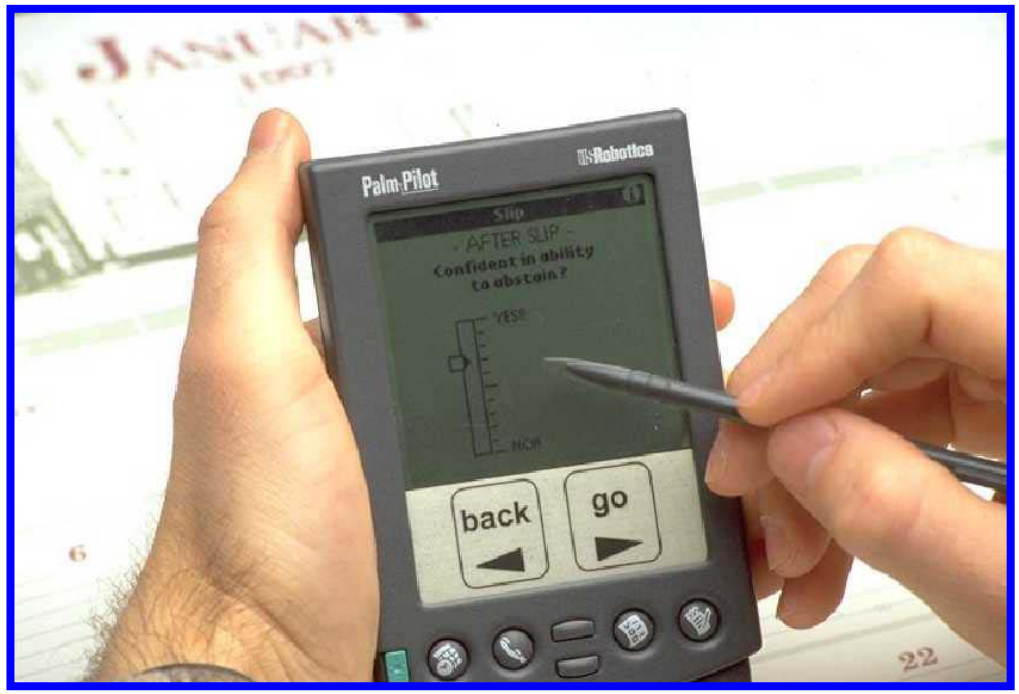
Timely Completion of Diaries: Paper vs. Electronic Diary

- Compared true compliance with paper vs. ED
- Electronically instrumented paper diary
- Pain patients: 3 entries/day
- Paper
  - Apparent compliance: 90%
  - Actual (best case) compliance: 11%
  - Hoarding: no opening on 1/3 of days, 92% of cards
- ED:
  - Actual compliance: 94%

Stone, Shiffman, et al, BMJ, 2002

Electronic Diaries

- Time-stamped
- Structured assessment
- Manage skips
- Computerized at source
- Compliance enhancement
- Prompting functions
- On-line smarts



Research Hypotheses

- Between-subject (aggregate):
  - Treatment, individual differences
  - Representative, reliable estimation of aggregate
- Within-subject (disaggregate):
  - Event incidence and characteristics
  - Often most interested in flow *over time*
  - Natural history, events, correlated processes, interventions
  - Sampling time and contexts, within-person variability
- Interactions

Sampling in EMA

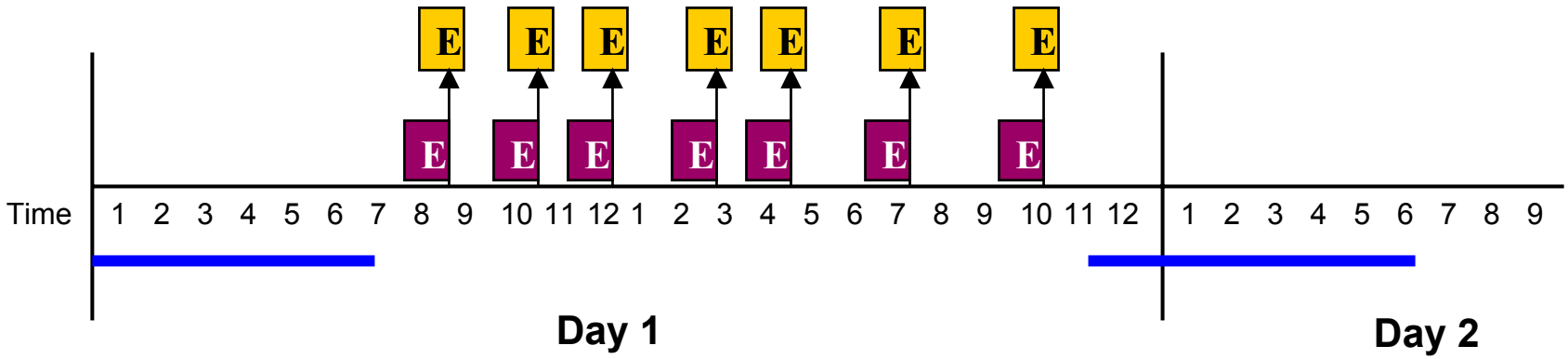
- Using “moments” to characterize process, person
- Within-subject sampling of moments is central
- Traditional sampling considerations apply, e.g.,
  - Bias, representativeness, sample size
  - Stratification, oversampling, etc.

Sampling Designs

- Event-based
  - Self-monitoring (e.g., meals, exercise)
- Time-based
  - Fixed time
    - By intervals (e.g., every 4 hours, daily)
    - By milestone (e.g., bedtime, morning+afternoon+evening)
    - Sometimes retrospective over inter-diary interval
  - Varying (random) time
    - Experience Sampling Method (e.g., random sampling)
    - Representative sample of “states”

After Wheeler & Reese, 1991, Bolger et al, 2003

Event-Based Sampling



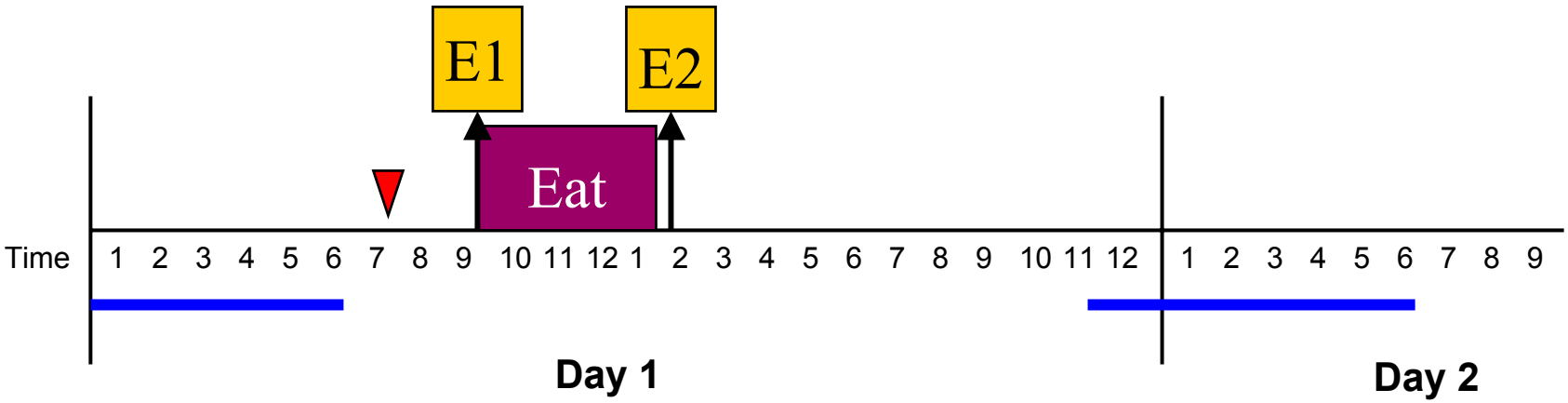
KEY:

E = Eating episode

E = Event report

= Sleep

Event-Based Sampling: Pre-Post



KEY:

= Meal

E

= Event report

= Sleep

Event Sampling Issues

- Defining the event
  - Operational definition
  - Thresholds: intensity, duration
  - Device-triggered events (e.g., vigorous movement)
- When to report
  - Beginning (reactivity, definition)
  - End (recall, forgetting, definition)
  - Both: change, duration
- Difficult to estimate under-reporting, missed episodes
- Possible biases in detection / reporting
  - Intensity, duration
  - Timing and context
- Reactivity, esp. in behavior change context

Purposes

- Count / frequency
  - # of eating occasions
- Characteristics
  - What was eaten
- Context & Antecedents
  - Where, with whom, how feeling…
  - Associations
    - Base rate problem
    - Case control designs

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	Classic Epi	**EMA**
Sampling units	People	Moments
Cases	Breast cancer	Eating episodes
Controls	Healthy controls	Random
'Ind. ' variable	Dietary fat	Mood

Time-Based Strategies

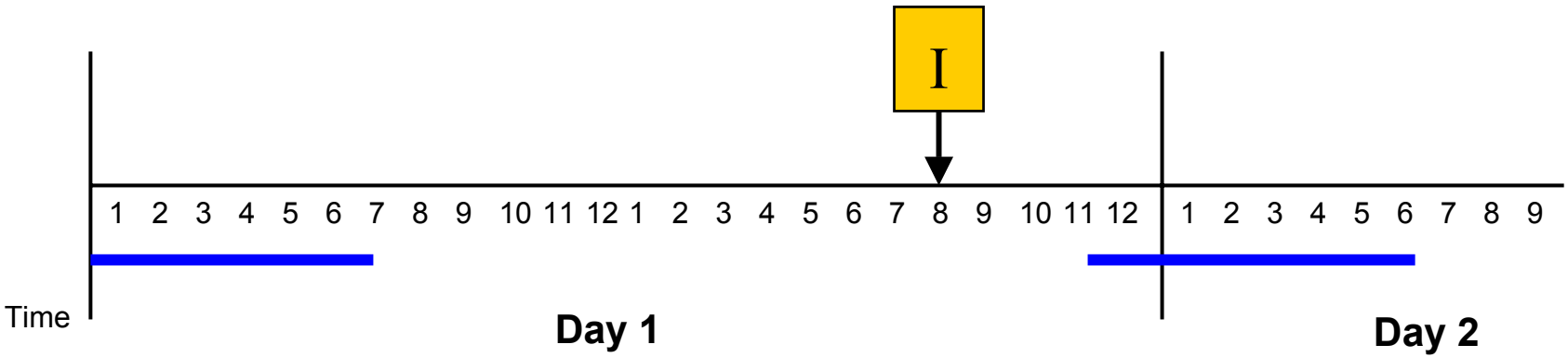
Fixed intervals

- Regular
- Complete coverage
- Recall
- Triggered by clock or milestone
- Traditional diary

Varied intervals

- Random
- Sampling
- Momentary
- Triggered by signal
- Experience Sampling Method

Fixed Interval: Daily



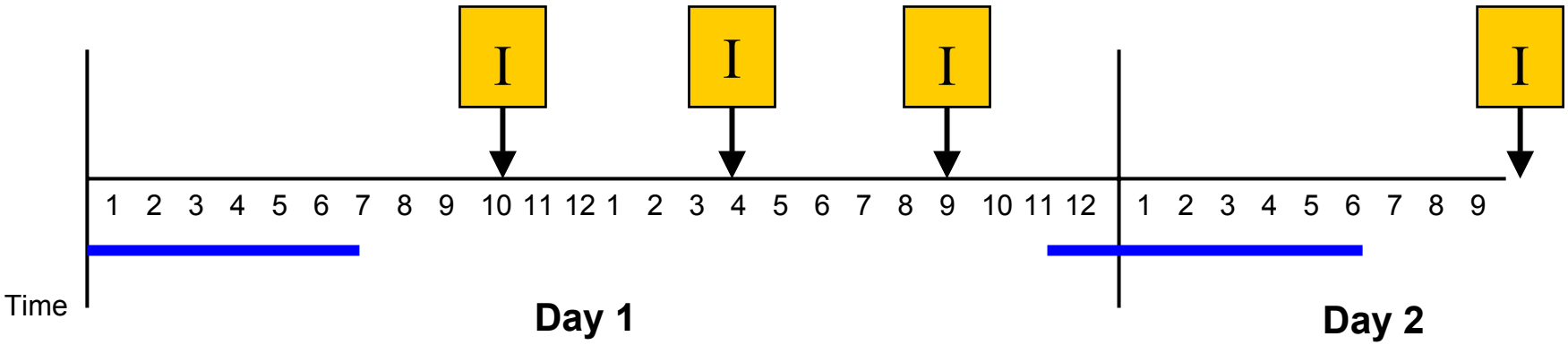
KEY:

I = EOD report

= Sleep

- Example:
  - Consumption of fruits and vegetables; sun exposure; pain; nausea; fatigue

Fixed Interval: > Daily



KEY:

I = Interval-based report

= Sleep

- Example:
  - Morning/afternoon/evening experience or symptoms: fruits & veggies; sun exposure; pain; nausea; fatigue

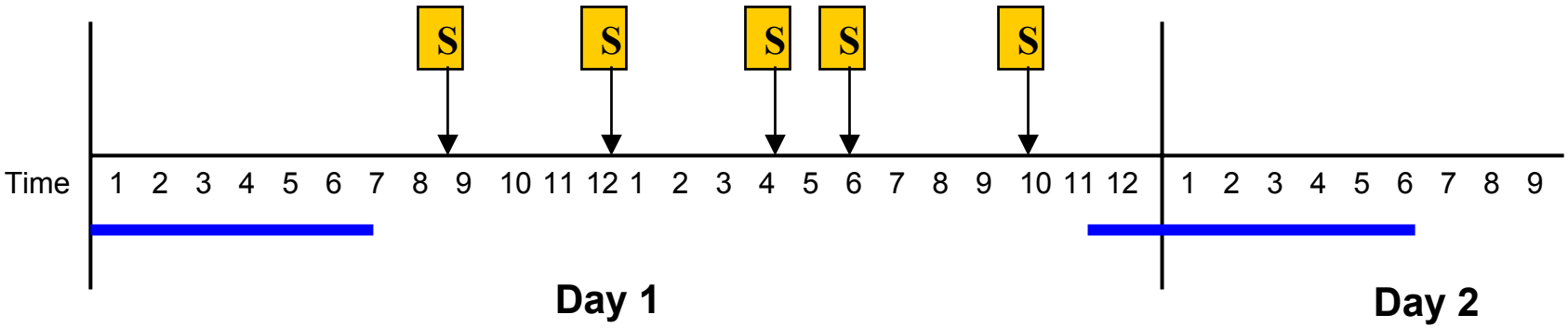
Fixed-Interval Issues

- Prompting assessments
  - Clock, Milestone (“bedtime”), Prompts
- Specificity of target time or window
  - “Evening”, “Bedtime”, 6 p.m. (± 10 minutes)
- Potential bias in timing
- Predictable demand
- Entraining to natural events

Random Time Sampling

- Experience Sampling Method
- Claim to representativeness
- Sampling schemes
  - Stratified random, over-sampling etc
- Requires devices to handle:
  - Scheduling
  - Prompting

Signal-Contingent



KEY:

S = Signal-based pain report

= Sleep

- Example:
  - Pain; nausea; fatigue; tobacco craving

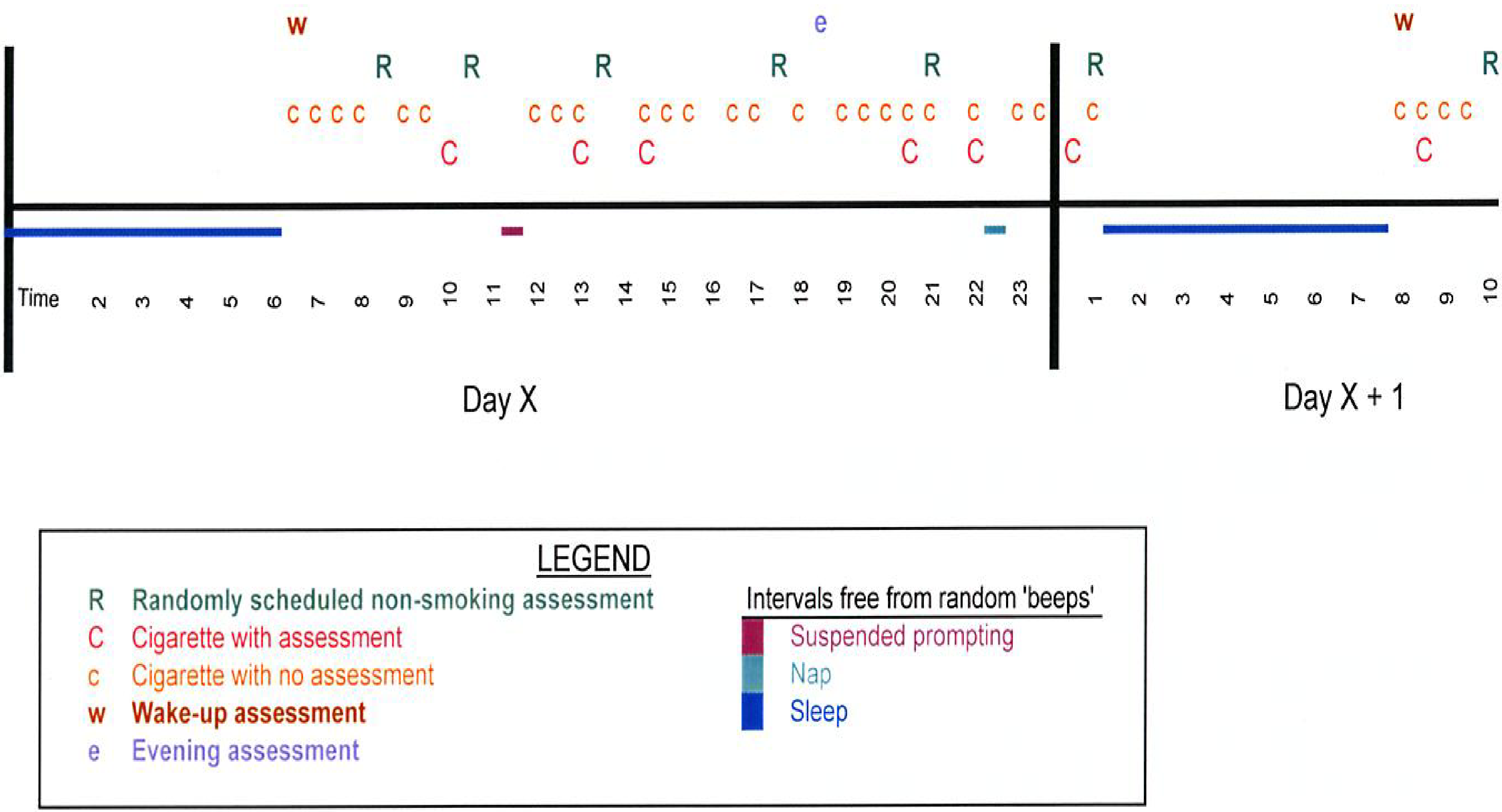
Random Time Sampling

- Arguably representative
  - Adaptive, may allow full 24/7 coverage
- Variations in sampling plans
  - Stratified sampling ensures better coverage
  - Weighted sampling or over-sampling
- Prompting
  - Device and subject issues
  - Need to provide time-out's
  - Prompting duration & window
- Controls for events

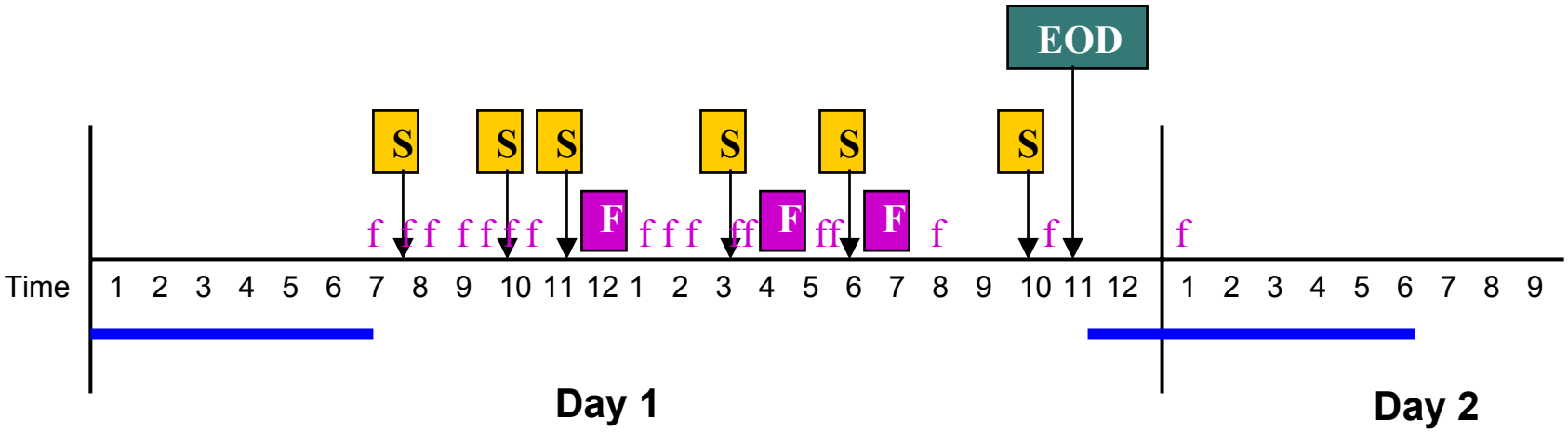
Mix & Match

- Can combine sampling schemes to fit research purpose and natural history of the phenomenon under study

SCHEMA FOR EMA ASSESSMENT OF SMOKING OVER THE DAY



Events in Context



case-control design

KEY:

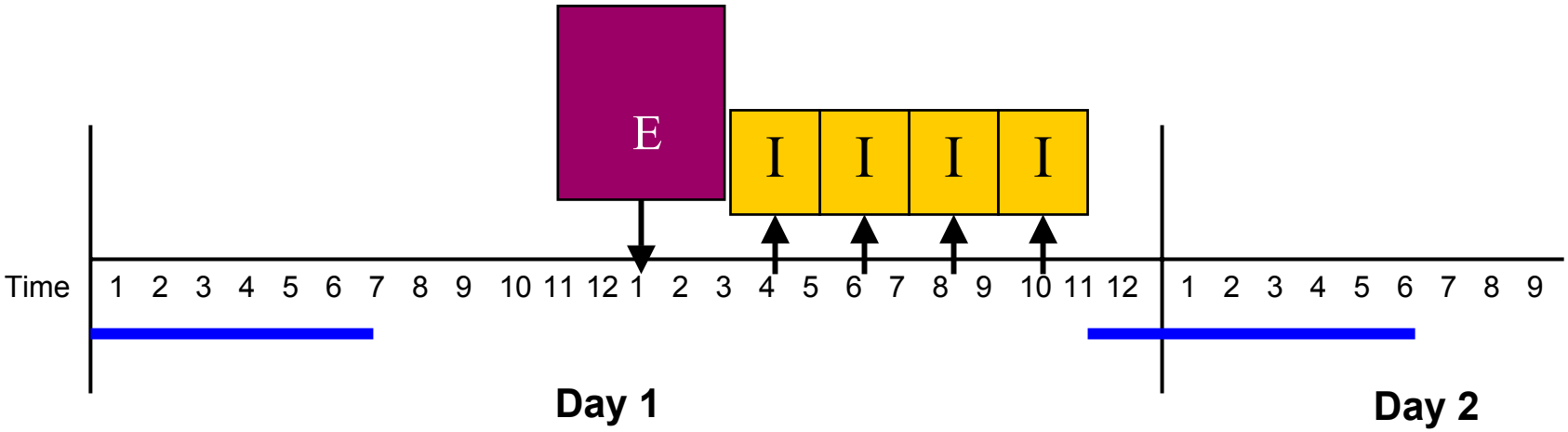
F = Event report = food, sampled (f)

S = Signal-based, random non-food assessment

EOD = End of Day report, stressful events

= Sleep

Follow-Up of Events



KEY:

E = Event: Exercise

I = Fixed-interval report of mood

= Sleep

Sampling summary

- Event-based
  - Suitable for episodes of activity & eating
  - Capture frequency, characteristics of episodes
- Fixed time
  - Time course
  - Time-series analysis
  - Potentially biased sampling
- Variable time, random sampling
  - Most suitable for continuously-varying phenomena
  - Representative sampling; strategic sampling

How Much Data Do I Need?

- $N_{Observations}$ =
  - # of observations / day X
  - # of days X
  - # of subjects
- Trade-offs
- It depends … on hypotheses, target frequency, variability
- Formal power analyses not worked out

Density of Assessment

- Balance data greed and practicality
- Control over behavior is often local, proximal
- Controlling variables are volatile, fast changing
  - e.g., mood, situation, cue exposure

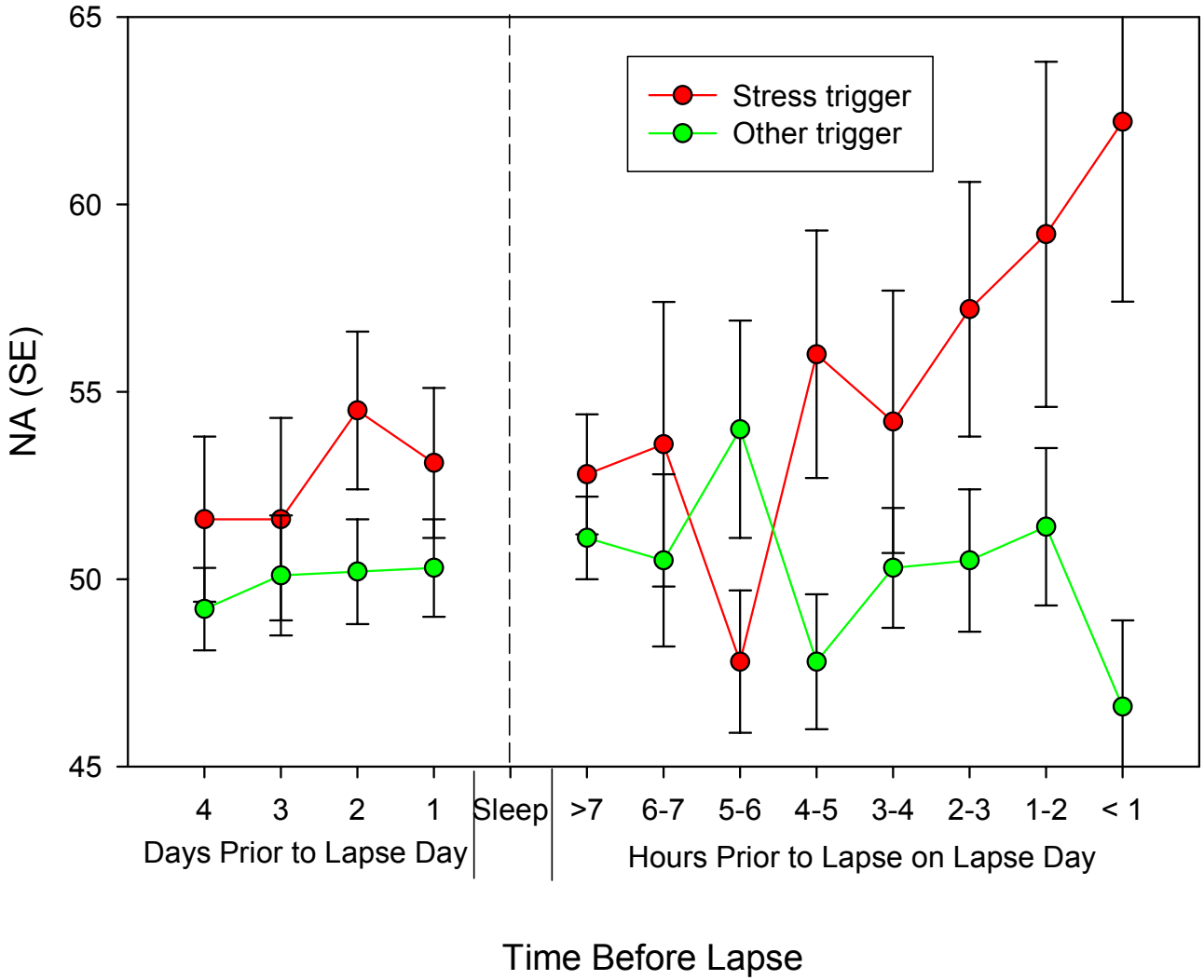
Special Issue for Activity & Eating

- Expectation of behavior change & self-presentation
- Eating
  - Collecting detailed food intake data
- Activity
  - Omission is a non-event
  - Subject to physical measurement

Summary

- Range of diary designs
- Many critical sampling decisions
- Technology: help and burden
- Balance of data hunger and practicality
- Prior knowledge of target phenomenon & piloting often needed
- Plan for analysis
- Design must be driven by research questions

Negative affect in the Days & Hours Before a Smoking Lapse

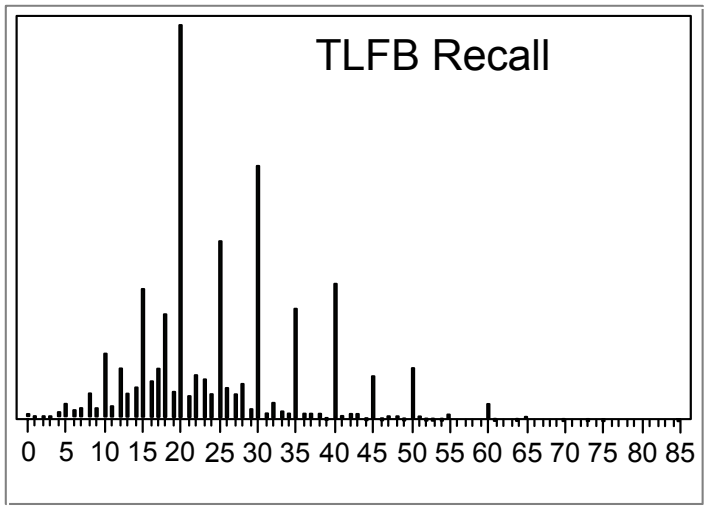


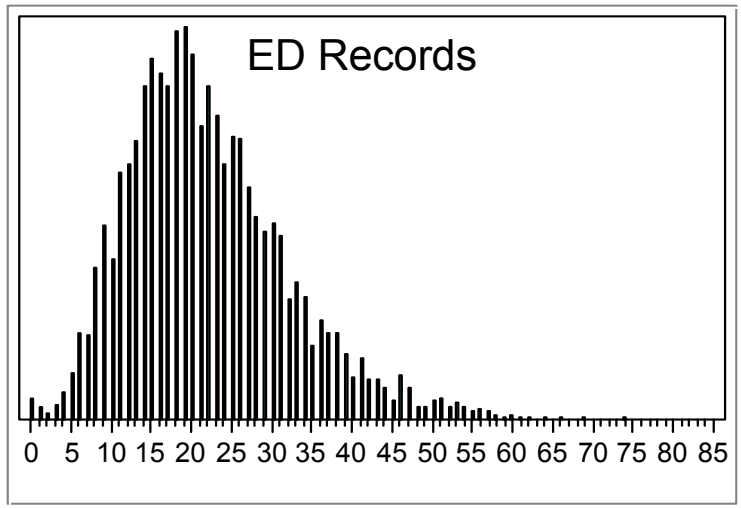
Assessing Events

- Recording vs. Assessing
  - Assessment increases burden
- Sampling of events for assessment
  - Reducing overall burden
  - Equalizing burden across subjects with differing frequency
  - Sampling schema
    - Random
    - Attribute-based
    - Stratified
  - Sampling rates; higher rates =
    - Precision of estimates
    - Relevant events

Digit Bias in Event Counts

DISTRIBUTION OF CIGARETTE COUNTS OVER DAYS





Time-Based Sampling Issues

- Recall interval
  - Complete (“since last assessment”)
  - Partial (“last 30 minutes”)
  - Momentary (“right now”)
- Assessment frequency / density
  - Match to expected “time-base” and trajectory of target
  - Frequent assessments can
    - Diminish recall interval
    - Provide more detailed data and time-line
    - Increase precision of estimates
    - Increase subject burden, possibly decrease compliance

Data-Analytic Models

- Not your father's t-test
- Intense within-subject repeated measures
- Time, sequence, and events as factors
- Multi-level models
  - Account for observations within person, condition, etc.
- Time-focused analyses
  - Trajectories
  - Time-to-event models w time-varying predictors
  - Spline regression

Inferences from EMA Data

- Typically still correlational, ecological data
- Improving inferences
  - Temporal sequence
  - Assessing confounding variables
- Common potential confounds
  - Time of day
  - Day of week
  - Concurrent state

Issues & Challenges

- Investigator: Cost, complexity
  - Devices
  - Data management
  - Analysis
- Participants: Burden
- It’s still self-report